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(56) Documents Cited
GB 2265274 A GB 2151872 A GB 1583737 A
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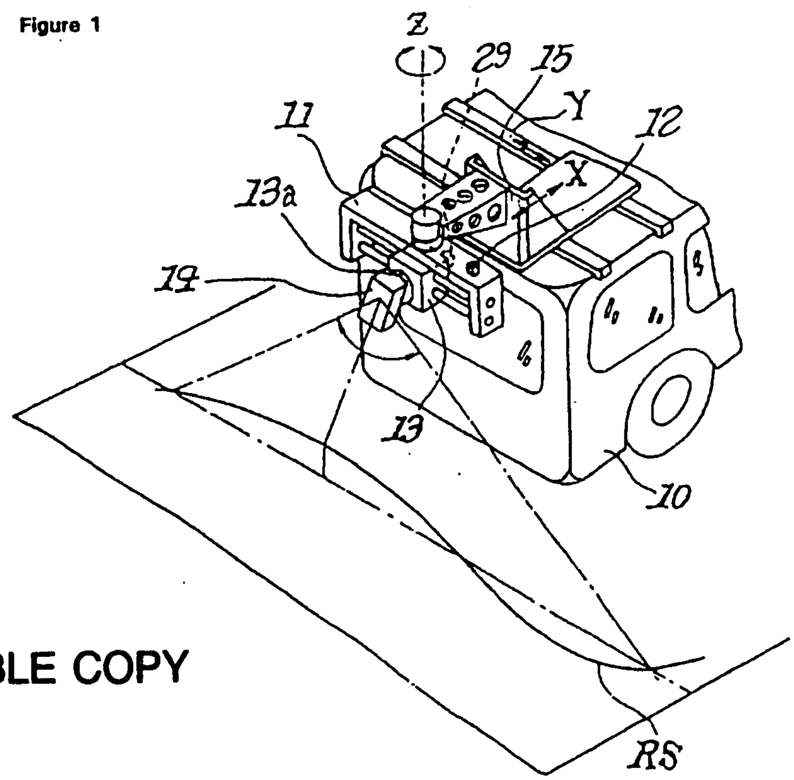
INT CL[6] G01B , G01C , G01S
Online: WPI

(54) **Road surface profilometer**

(57) The profilometer is mounted on a moving vehicle. It comprises a pulse lidar 14 which is rotated about a horizontal axis pointing in the direction of movement of the vehicle. The position of the point of the road which is examined is determined from the distance that the vehicle has travelled, its orientation, and the amount that the lidar has been turned. An indication of the shape of the road (concave, convex or inclined) is displayed.
The rotational motion may be converted into reciprocal motion.

Figure 1



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print incorporates corrections made under Section 117(1) of the Patents Act 1977.

Figure 1

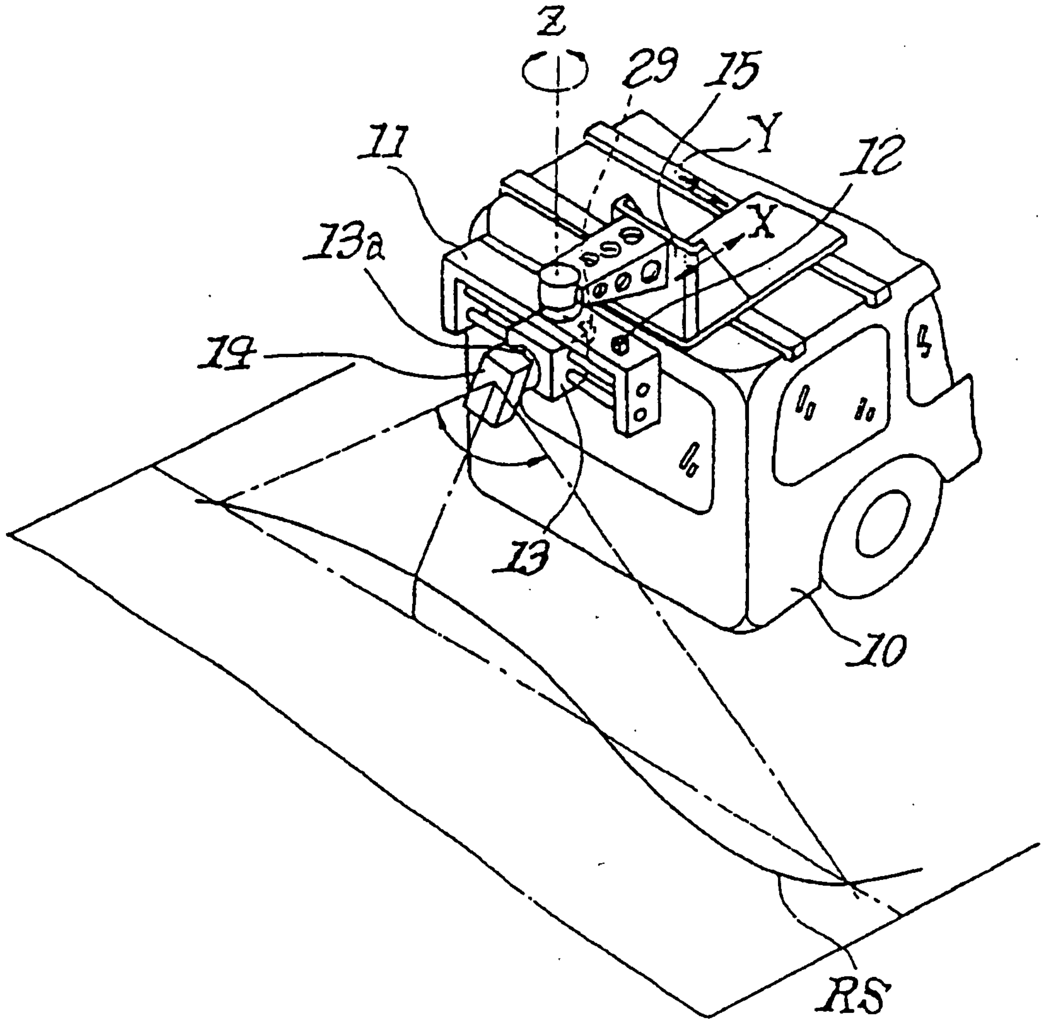


Figure 2

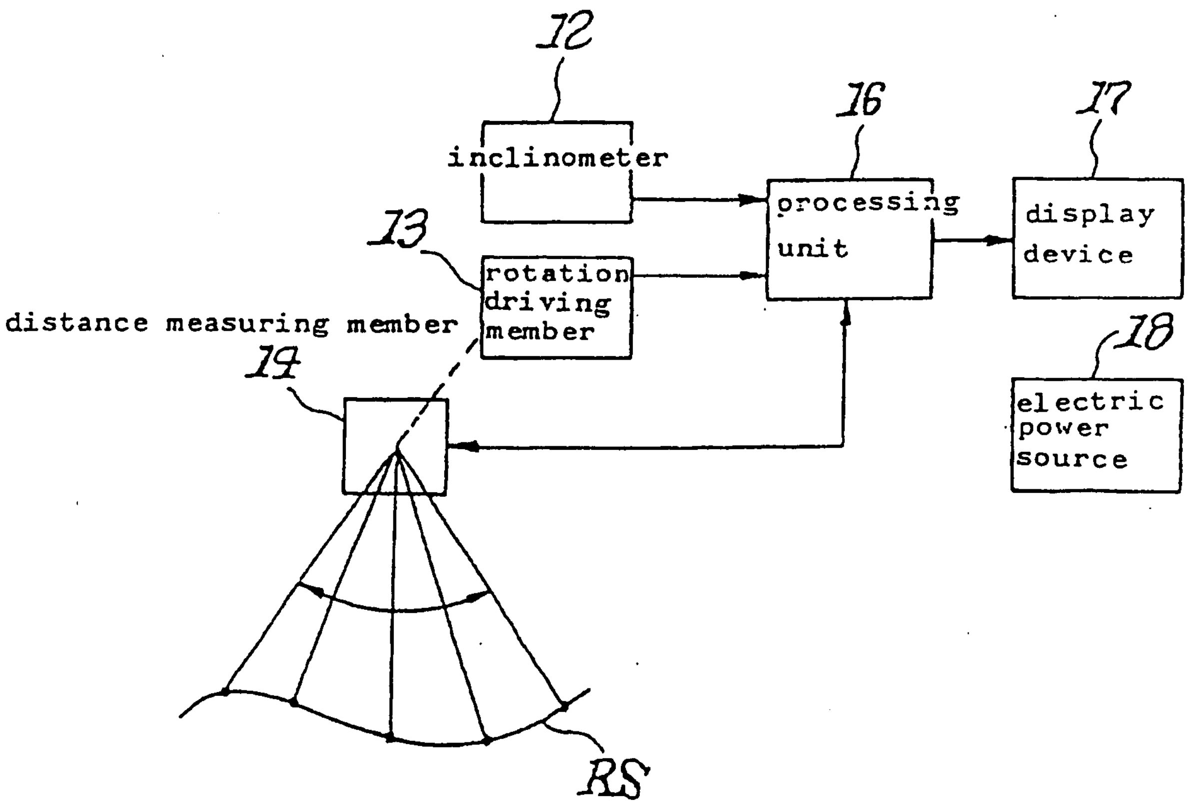

12
16
17
inclinometer
processing unit
display device
13
rotation driving member
distance measuring member
18
14
electric power source
RS

Figure 3

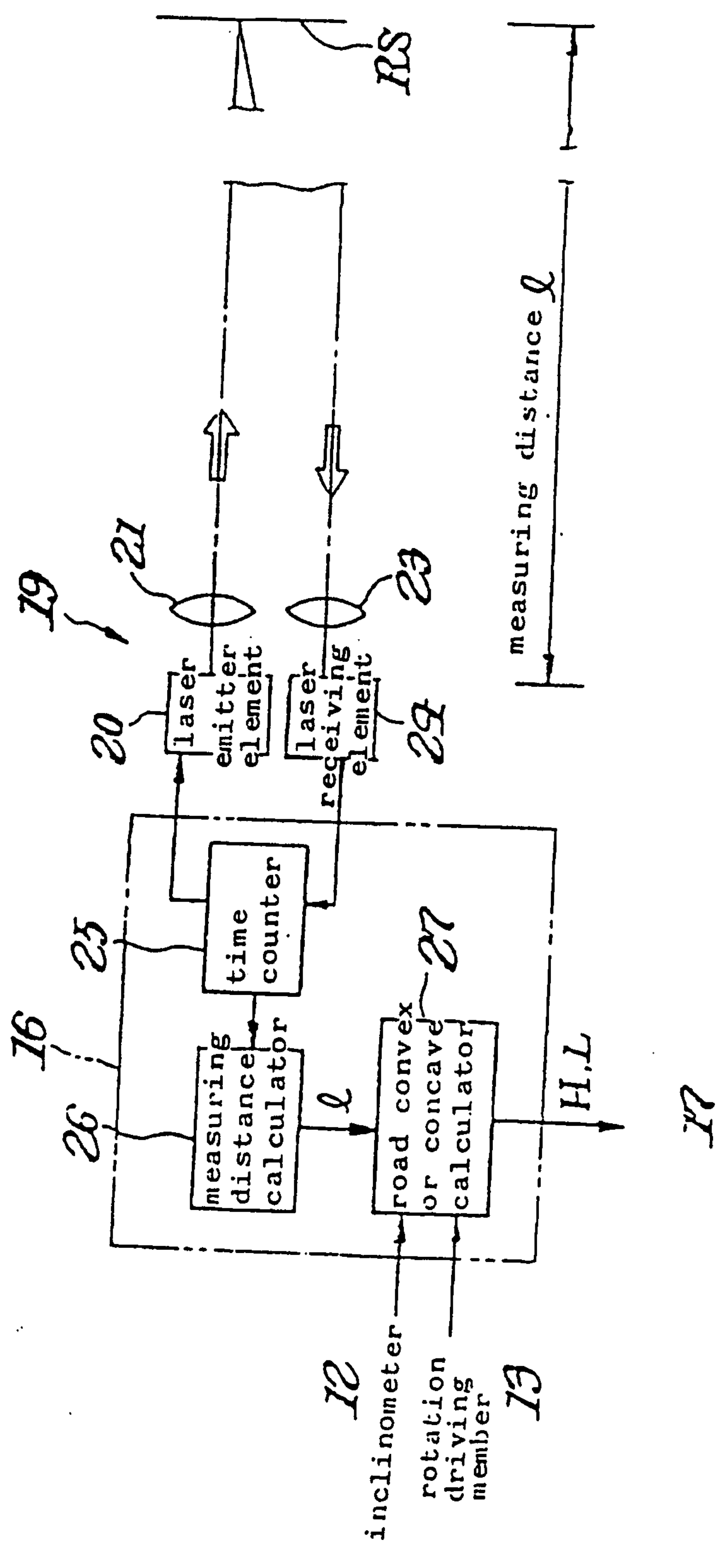

RS
measuring distance ℓ
21
23
19
laser emitter element
laser receiving element
20
22
time counter
25
measuring distance calculator
26
16
ℓ
road convex or concave calculator
27
H,L
17
inclinometer
12
rotation driving member
13

Figure 4

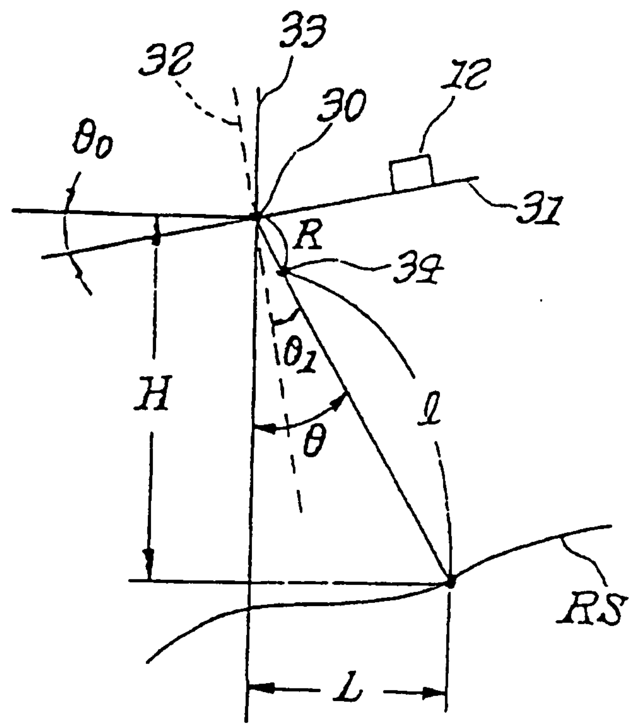
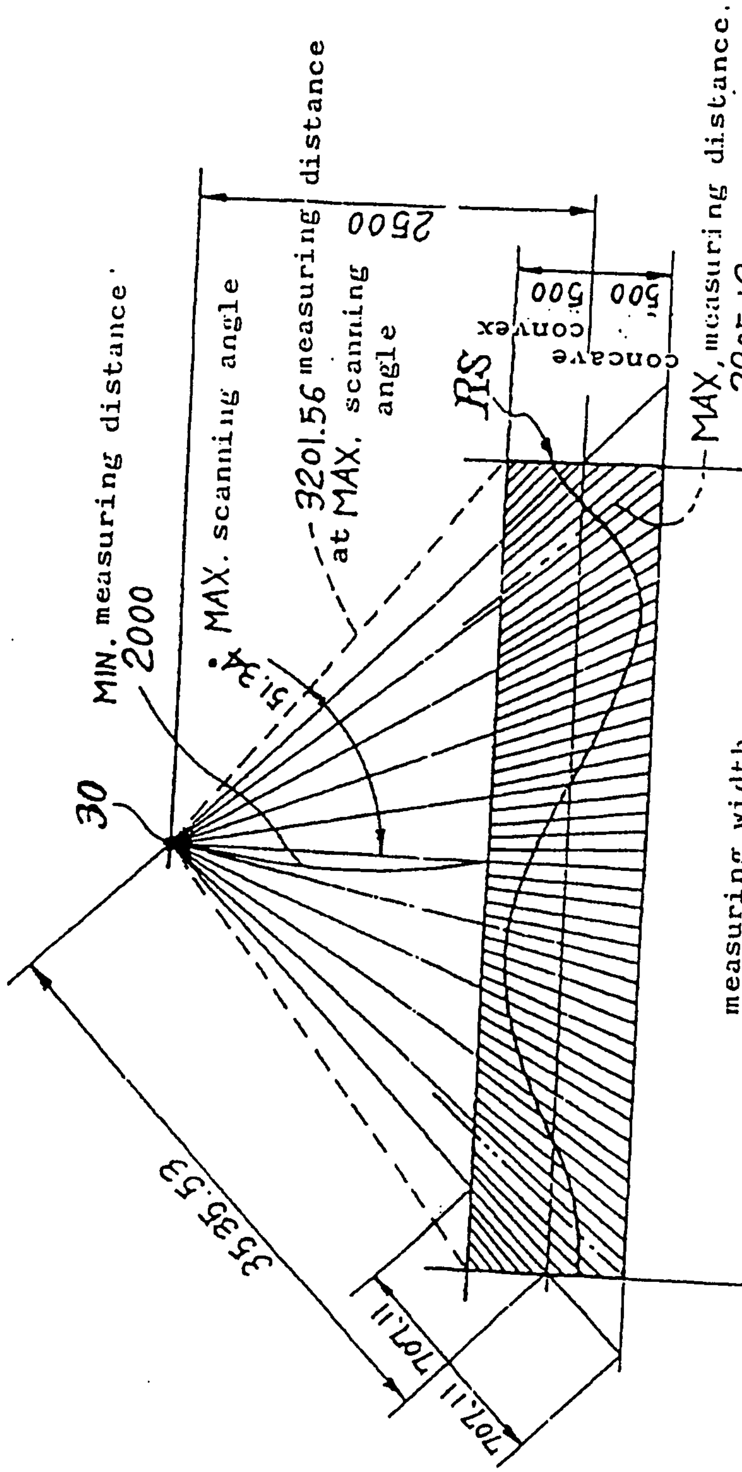


Figure 5



MIN. measuring distance
2000
MAX. scanning angle
151.34°
3201.56 measuring distance
at MAX. scanning angle
2500
500
500
convex
concave
RS
MAX. measuring distance
3905.12
measuring width
5000
30
3535.53
707.11
707.11

Figure 6

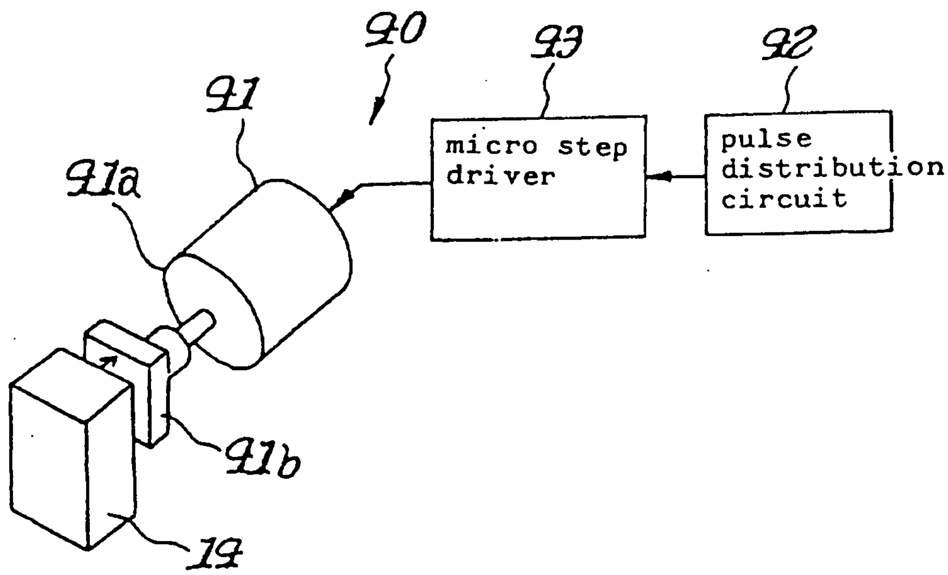


Figure 7

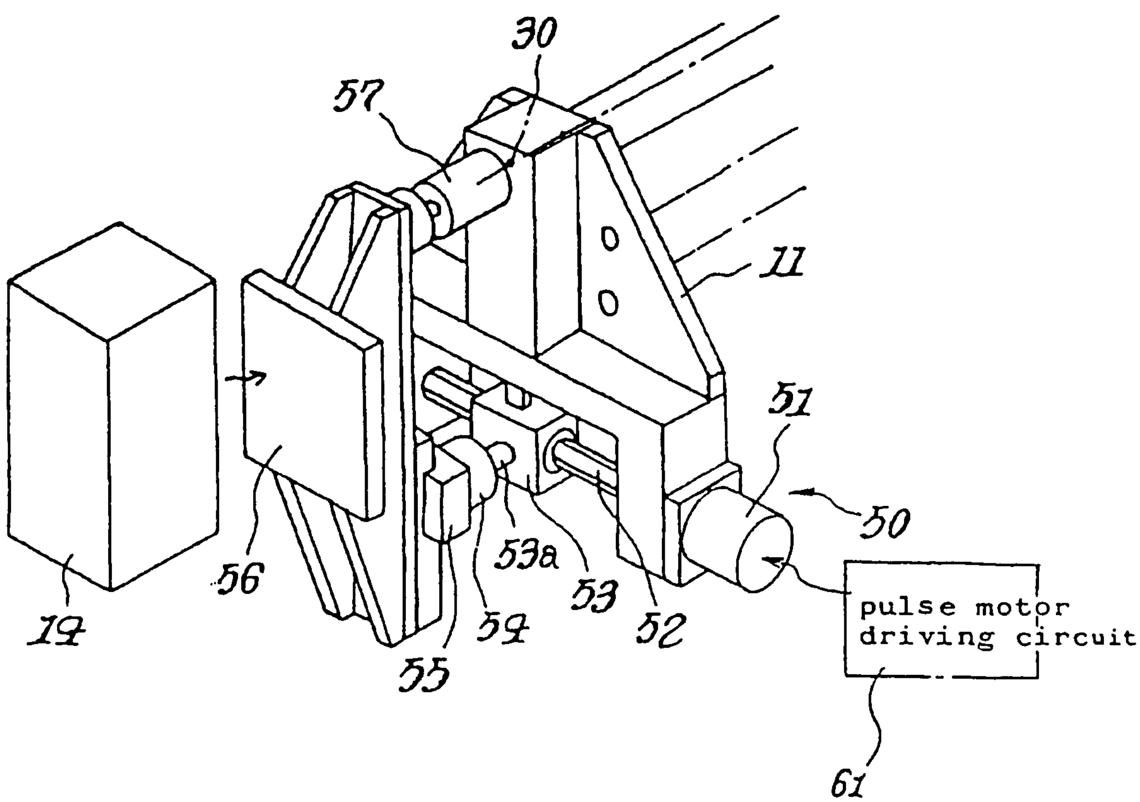


Figure 8

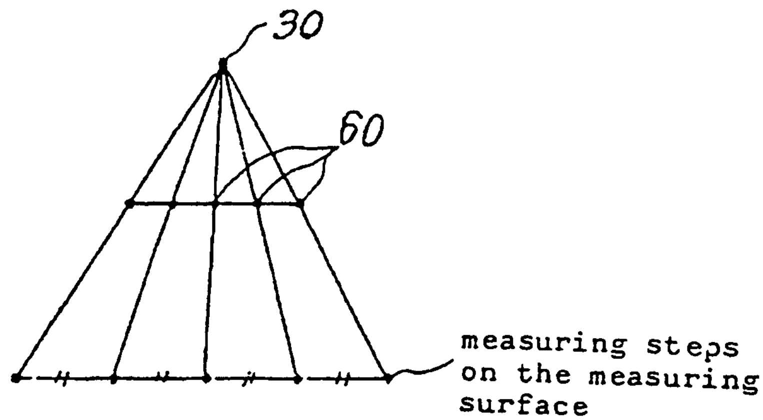
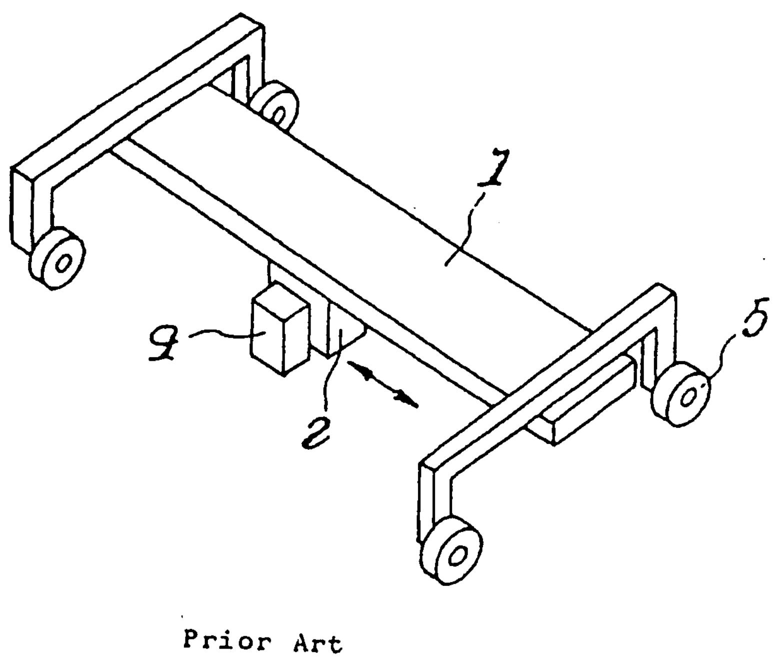
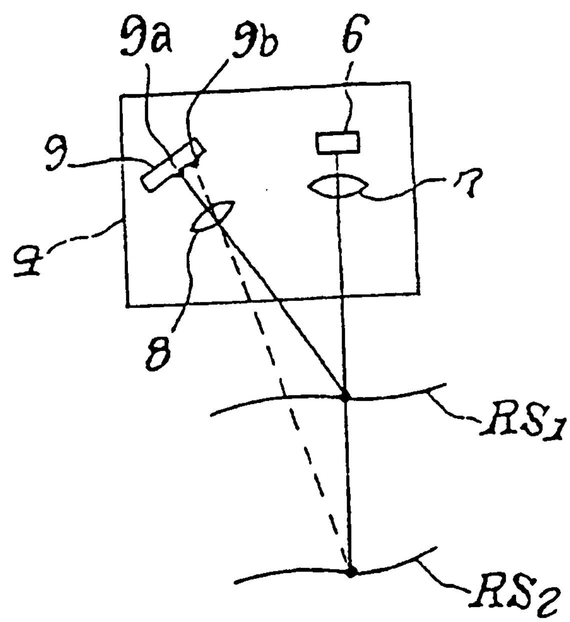


Figure 9



Prior Art

Figure 10



Prior Art

Figure 11

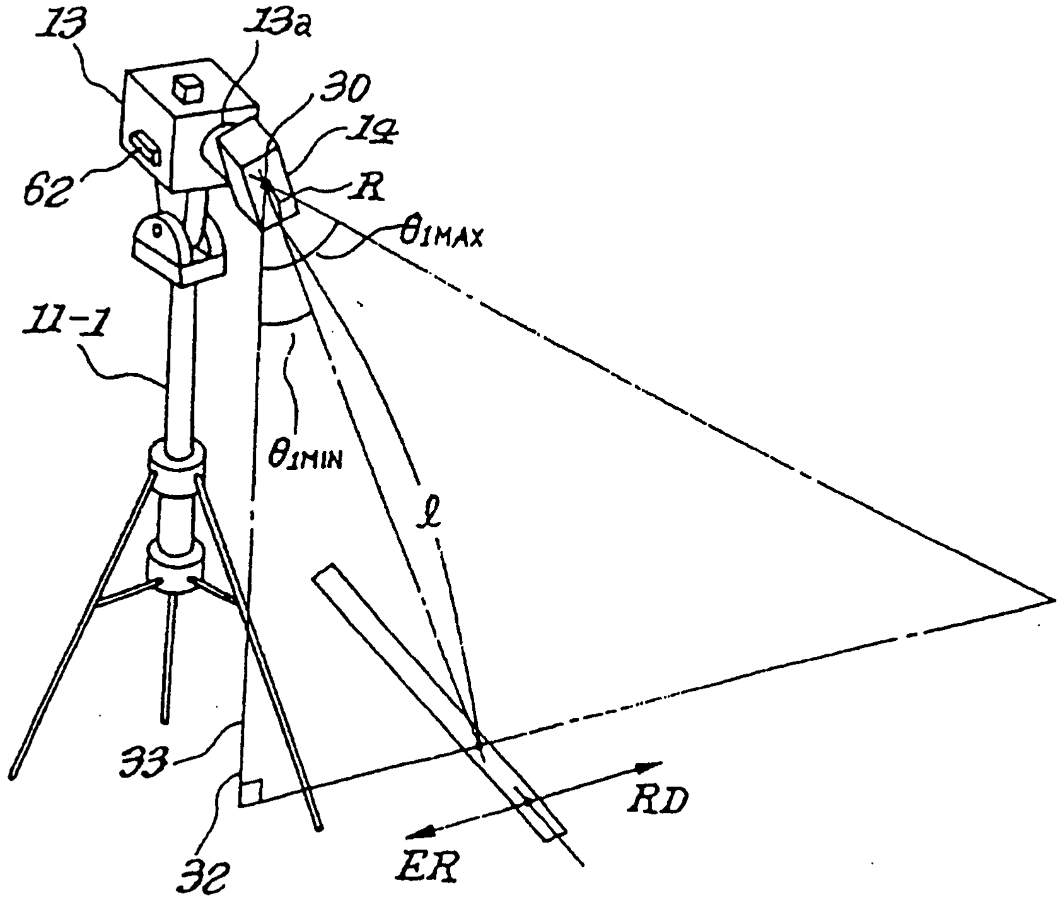


Figure 12

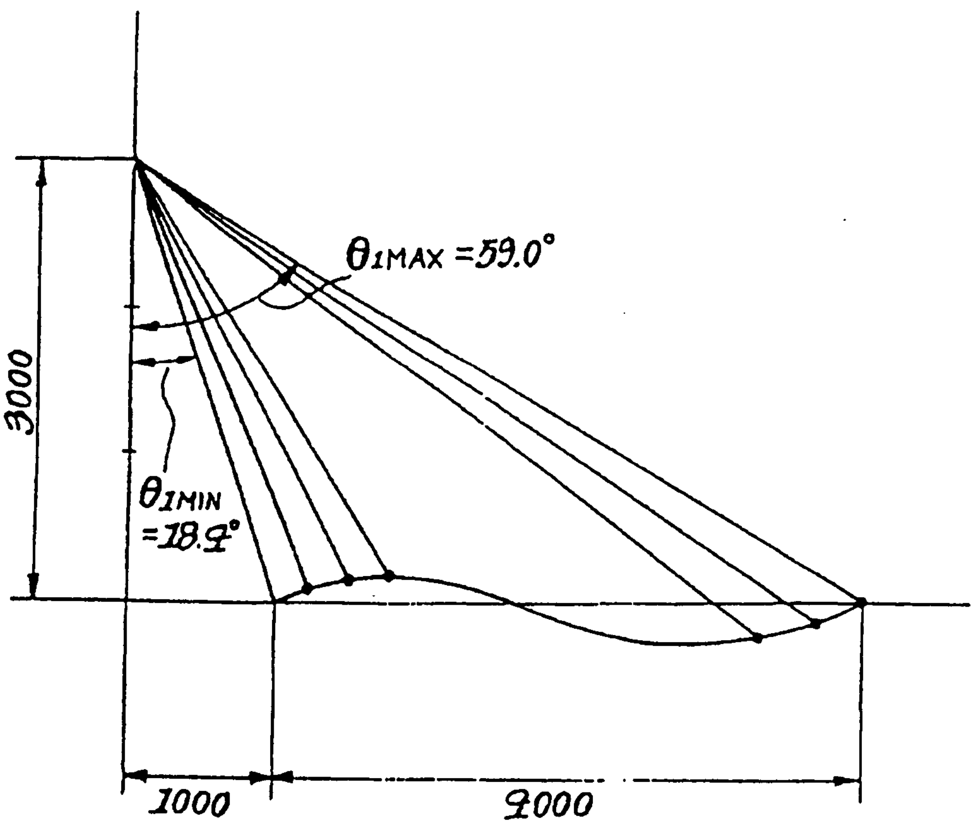
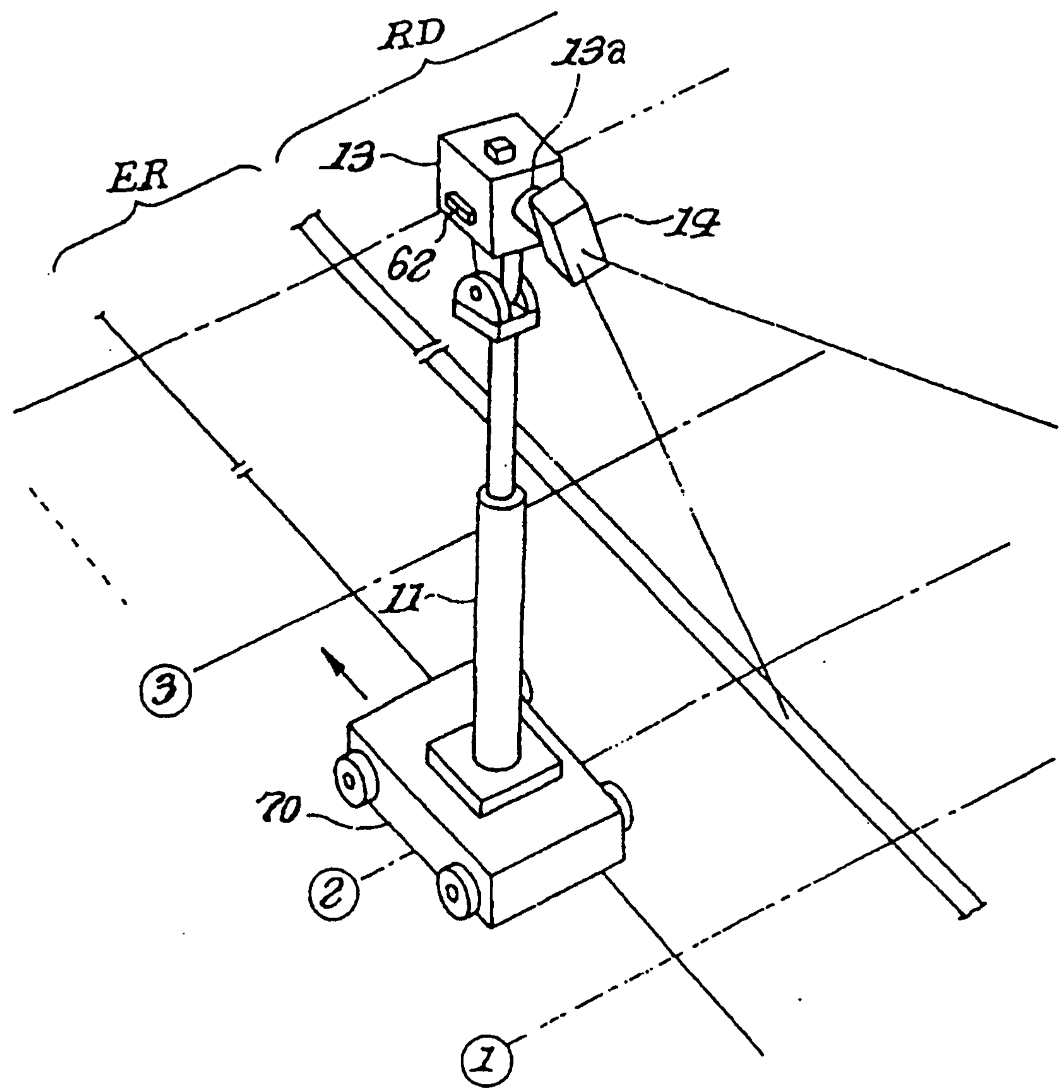


Figure 13



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AN APPARATUS FOR MEASURING A SHAPE OF ROAD SURFACE

This invention relates to an apparatus mounted on a vehicle for measuring roughness of a road surface, such as convex, concave or inclination without contacting the road surface.

A conventional apparatus for measuring roughness of the road surface is shown in Fig. 9. In Fig. 9, reference numeral 1 denotes a main frame having a width corresponding to a road to be measured. Main frame 1 is supported by wheels 5 at its either end. Carriage 2 is supported at the bottom face of main frame 1 so as to slidably run in a longitudinal direction of main frame 1, and measuring member 4 is fixed to carriage 2. As main frame 1 is pulled by the vehicle in its lateral direction, measuring member 4 moves above the road surface.

When measuring the shape of the road surface, carriage 2 is moved in a longitudinal direction of the main frame 1 by a motor not shown and measuring member 4 measures a distance from the road surface.

Fig. 10 shows a principle of measuring according the apparatus. Measuring member 4 includes laser emitter element 6, projector lens 7, receiving lens 8, and CCD elements 9. Laser light from laser emitter element 6 is projected to the road surface through projector lens 7. A part of a reflected light from the road surface gathered by receiving lens 8, reaches to CCD elements 9. A position of the received light in CCD elements 9 varies depending on the distance between the road surface and measuring member 4. For example, if the road surface varies from RS 1 to RS2, a position of the received light varies from 9a to 9b. Therefore, the distance from the road surface can be known from the receiving position in CCD elements 9, so that it is

possible to measure concave or convex on the surface of road by measuring receiving positions as carriage 2 is moved along frame 1.

However, in the conventional apparatus, if a width of the road to be measured becomes longer, for example 3m, the length of main frame 1 must be longer. Consequently, a mechanism of supporting carriage 2 and a mechanism of driving carriage 2 become bulky, and it needs complicated structure to control precise positions of carriage 2 over an entire running stroke of carriage 2 along the main frame, which results in that not only its cost is increased but the apparatus becomes heavy and a number of necessary human labors for carrying and operating is increased.

The frame can be substituted for a telescopic frame which can expand its length to have a longer measuring width than the length of the frame in its shrunk status. However such a mechanism is complicated and has problems in weight and cost.

To eliminate the above disadvantages, it is an object of this invention to provide an apparatus for measuring roughness of a road face, which has a small size and a low weight.

It is another object of this invention to provide an apparatus for measuring roughness of a road surface inwhich an operator needs not get out of the vehicle during measuring and get rid of dangerous outdoor works on the road.

It is still another object of this invention to provide an apparatus for measuring roughness of a road surface which can decrease human labors.

In this invention, an apparatus for measuring roughness of a road surface such as convex, concave or inclination on the road surface is mounted on the vehicle and comprises a rotation

driving member to generate rotation motion in a vertical plane and to output a signal concerning its rotation angle. The apparatus further comprises an inclinometer to detect an inclined angle of the rotation driving member, and a distance measuring member rotated by the rotation motion of the rotation driving member and to measure a distance from the road surface. A processing unit calculates a vertical distance and a horizontal distance between the apparatus and the road surface by means of the inclined angle detected by the inclinometer and the rotation angle detected by the rotation driving member.

The distance measuring member may be a light wave distance measuring equipment measuring distance by emitting a light wave toward the road surface and receiving its reflected light.

The rotation driving member may comprise a pulse motor for generating the rotation motion, and a pulse motor driver for driving the pulse motor. The pulse motor driver outputs a signal regarding to the rotation angle of the rotation motion.

Alternatively, the rotation driving member may comprise a pulse motor for generating the rotation motion, a transmission mechanism for transducing the rotation motion from the pulse motor into reciprocal linear motion and further for transducing the reciprocal linear motion into rotation motion in a vertical plane about a certain rotation center of the apparatus, and a pulse motor driver for driving the pulse motor. The pulse motor driver outputs a signal regarding to the rotation angle of the rotation motion from the pulse motor.

The above, and other objects, advantages and novel features of this invention will become apparent from the following detailed description and the accompanying drawings, in which like reference numbers indicate like or similar parts throughout wherein;

Fig. 1 is a perspective view of an apparatus for measuring a shape of a road surface of an embodiment according to the present invention,

Fig. 2 is a block diagram of the embodiment of Fig. 1,

Fig. 3 is a block diagram of a light wave distance measuring equipment and a signal processing unit of the embodiment of Fig. 1,

Fig. 4 is an explanation view showing operations of the embodiment of Fig. 1,

Fig. 5 is a measured result of the apparatus shown in Fig. 1,

Fig. 6 is perspective view of a rotation driving mechanism of an apparatus for measuring a shape of a road surface of an another embodiment of this invention,

Fig. 7 is a perspective view of a rotation driving mechanism of an apparatus for measuring a shape of a road surface of a yet another embodiment according to the present invention,

Fig. 8 is an explanation view showing scanning of the apparatus of Fig. 7,

Fig. 9 is a perspective view of an apparatus for measuring a shape of a road surface of the conventional device,

Fig. 10 shows principle of measuring of the conventional apparatus,

Fig. 11 is a perspective view of an apparatus for measuring a shape of a road surface of a still another embodiment according to the present invention,

Fig. 12 is a measured result of the apparatus shown in Fig. 11,

Fig. 13 is a perspective view of an apparatus for measuring a shape of a road surface of a further another embodiment according to the present invention.

Referring to Fig. 1 , an embodiment of the invention is described below. The apparatus for measuring a shape of a road surface of the embodiment is mounted on measuring vehicle 10. Reference numeral 11 denotes a frame fixed on measure vehicle 10, otherwise supported to measuring vehicle 10 by ON/OFF line carriage 15 if necessary, and its position in a horizontal plane (X-Y plane) and its angular position about a vertical axis (Z axis) are adjusted by carriage 15. Inclinometer 12 is provided on frame 11 for detecting an inclined angle of a longitudinal direction of frame 11 relative to the horizontal plane and for outputting a signal of the detected inclined angle. Rotation driving member 13 fixed to frame 11 includes a driving motor for generating rotary motions, and angular transmitter 29, such as potentiometer or encoder for detecting a rotational angle of output shaft 13a of the driving motor and for outputting a signal of the detected rotational angle to processing unit 16 explained hereinafter. A signal from the processing unit 16 in accordance with the signal from the transmitter 29 is feedbacked to the driving motor which controlled by this conventional servo control system.

Inclinometer 12 may be directly fixed to a housing of rotation driving member 13 fixed to frame 11 to detect an inclined angle of rotation driving member 13.

Distance measuring member 14 is attached to rotary output shaft 13a of rotation driving member 13. It is desired that attachment of distance measuring member 14 to rotation driving member 13 and attachment of rotation driving member 13 to frame 11 should be completed with a certain precision before frame 11 is fixed to measure vehicle 10.

Distance measuring member 14 is provided with light wave distance measuring equipment 19 (see Fig. 3) which transmits light wave to a road surface. Distance measuring equipment 19

reciprocally swings right or left in a vertical plane by rotation driving member 13 so that the light axes of light from equipment 19 traverse the road surface. As shown in Fig. 2, the signal from light wave distance measuring equipment 19 is fed to processing unit 16 mounted on measure vehicle 10, together with the signals from angular transmitter 29 of rotation driving member 13 and from inclinometer 12. Processing unit 16 connects to display device 17. Electric power source 18 is also mounted on measure vehicle 10 and feeds electric power to rotation driving member 13, light wave distance measuring equipment 19, processing unit 16 etc..

Processing unit 16 includes time counter 25, measuring distance calculator 26 and road convex or concave calculator 27 (see Fig. 3). Measuring distance calculator 26 calculates a distance from light wave distance measuring equipment 19 to the road surface and road convex or concave calculator 27 obtains data regarding to convex or concave of the road surface by means of the outputs from inclinometer 12 and angular transmitter 29 of rotation driving member 13.

Fig. 3 shows principle of measuring of light wave distance measuring equipment 19 which includes laser emitter element 20, projector lens 21, receiving lens 23 and laser receiving element 24. Laser emitter element 20 emits laser pulse lights every predetermined time interval, each of which is transduced to a parallel light by projector lens 21 and illuminates road surface RS. A part of a reflected light from road surface RS is gathered by receiving lens 23 and reaches to laser receiving element 24. Time counter 25 of processing unit 16 counts clock pulses from when a trigger signal is fed to laser emitter element 20 to emit the laser, to when the received signal is output from laser receiving element 24, and the number of the clock pulses is transduced to a distance l by measuring distance calculator 26.

The obtained distance l is fed to road convex or concave calculator 27 and processed as follows;

Fig. 4 shows operation of this apparatus. Reference numeral 30 refers to a rotation center of distance measuring member 14. Reference numeral 31 refers to longitudinal direction of frame 11, inclinometer 12 detects inclined angle θ_0 of a longitudinal direction, in other words, inclined angle of a fixed part of rotation driving member 13 deviated from the horizontal plane. Distance measuring member 14 attached to rotary output shaft 13a of rotation driving member 13 swings right or left about rotation center 30 and line 32 perpendicular to rotation driving member 13. Rotation angle θ_1 deviated from vertical line 32 is output from angular transmitter 29. Offset angle θ of light axis of distance measuring member 14 deviated from vertical line 33 is obtained by the following equation:

$$\theta = \theta_1 + \theta_0$$

wherein R is a distance from rotation center 30 to reference point 34 of distance measuring member 14 and l is a distance obtained by measuring distance calculator 26. Vertical distance H and horizontal distance L from rotation center 30 to a measuring point on road surface RS are obtained by the following equations.

$$H = (R+l)\cos\theta = (R+l)\cos(\theta_1 + \theta_0)$$

$$L = (R+l)\sin\theta = (R+l)\sin(\theta_1 + \theta_0)$$

Consequently, in road convex or concave calculator 27, output ${}_0$ from inclinometer 12 and output ${}_1$ from angular transmitter 29 of rotation driving member 13 are added and the added angle is used to calculate H and L. The calculated vertical distance H and horizontal distance L between rotation center 30 and the measuring point on the road surface are fed to display device 17 and plotted in a display of display device 17.

Fig. 5 shows an example of a measured result, maximum scanning rotation angle is 51.34 degree, measuring width is 5 m.

The lengths in Fig. 5 is shown in mm. Each measuring point is plotted by calculated vertical distance H and calculated horizontal distance L between the measuring point and rotation center 30.

As explained above, it is possible to reduce a size and weight of the apparatus by means of rotating distance measuring member 14 rotated by rotation driving member 13, resulting in low costs and less human labors.

Fig. 6 is another embodiment of the rotation driving member. In this embodiment, rotation driving member 40 includes pulse motor 41 as a drive motor, and angular transmitter 29 is omitted. Distance measuring member 14 is attached to output shaft 41a of pulse motor 41 through attaching plate 41a. Rotation driving member 40 further includes pulse distribution circuit 42 and micro step driver 43 connected to distribution circuit 42. Micro step driver 43 drives pulse motor 41 with a precision of a predetermined angle.

It is possible to drive pulse motor 41 by a predetermined stepped angle with a high resolution. Road convex or concave calculator 27 can obtain a signal corresponding to rotation angular signal output θ_1 of distance measuring member 14 from micro step driver 43.

Fig. 7 is another embodiment of the rotation driving member according to the present invention. Rotation driving member 50 in this embodiment includes pulse motor 51 as a drive motor and omits angular transmitter 29. In this embodiment, every stepped rotation driven by pulse motor 51 corresponds to a scanning interval in a horizontal direction in a measuring plane. Namely, an output shaft of pulse motor 51 disposed to be parallel to a longitudinal direction of frame 11 and rotatably supported to frame 1, integrally connects ball thread 52. Nut 53 is threadably engaged to ball thread 52. Linear guide plate 55 is

rotatably supported through bearing 54 to shaft 53a extending perpendicularly relative to thread 52 from nut 53. Mounting plate 56 is slidably supported to linear guide plate 55. An upper end of mounting plate 56 is rotatably supported to frame 11 through bearing 57. Distance measuring member 14 is fixed to mounting plate 56. Rotation movement from pulse motor 51 is transduced rotation movement about center 30 by a transmission mechanism consisting of ball thread 52, nut 53, bearing 54, linear guide plate 55, mounting plate 56 and bearing 57.

The operation of the above construction is carried out as follows. Pulse motor 51 rotates ball thread 52, moving nut 53 in a direction parallel to a longitudinal direction of frame 11. Mounting plate 56 rotates reciprocally about center 30 because the upper end of mounting plate 56 is rotatably supported to frame 11 through bearing 57 and slidably supported to linear guide plate 55 which moves in a direction parallel to the longitudinal direction of frame 11 together with nut 53.

As shown in Fig. 8, every rotation step of pulse motor 51 corresponds to a displacement point (60, 60,...) of nut 53 along ball thread 52, and lights from distance measuring member 14 are propagated in a direction from center 30 to displacement points 60, 60,... so that intervals of measuring step in a horizontal direction on the measuring surface become equal.

Road convex or concave calculator 27 obtains a signal corresponding to rotation angular output θ_1 from a pulse motor driving circuit 61.

In this embodiment, it is possible to utilize rack and pinion instead of ball thread 52 and nut 53.

Now, Fig. 11 is still another embodiment according to the present invention. An apparatus according to the present embodiment is positioned on sidewalk or outside of the road ER.

In Fig. 11, flame 11-1 disposed on sidewalk or outside of

the road ER, is an elevating tripod.

Rotation driving member 13 similar to the one in the first embodiment is fixed to a plane portion on the top of the flame 11-1. Distance measuring member 14 is mounted on output shaft 13a of rotation driving member 13. Level 62 is mounted on the housing of rotation driving member 13. Alternatively, level 62 may be directly mounted on flame 11-1.

Rotation driving member 13 also includes angular transmitter 29 not shown for detecting a rotational angle of output shaft 13a, as well as the first embodiment. Distance measuring member 14 is provided with light wave distance measuring equipment 19 which transmits light wave to a road surface as well as the first embodiment. Signals from light wave distance measuring equipment 19 and angular transmitter 29 are fed to a processing unit not shown. The processing unit also includes a time counter, measuring distance calculator and road convex or concave calculator as well as the first embodiment. Measuring distance calculator calculates a distance from light wave distance measuring equipment 19 to the road surface, and road convex or concave calculator 27 obtains data regarding to convex or concave of the road surface by means of the output from angular transmitter 29 of rotation driving member 13. The processing unit connects to a display device. An electric power source feeds electric power to rotation driving member 13 and light wave distance measuring equipment 19 etc..

In the apparatus according to this embodiment positioned on sidewalk or outside of the road ER, the housing of rotation driving member 13 and the plane portion on the top of the flame 11-1 are adjusted to keep horizontal before measuring.

As shown in Fig. 11, distance measuring member 14 attached to rotary output shaft 13a of rotation driving member 13 swings between θ_{1MAX} and θ_{1MIN} toward the road RD about rotation

center 30 from vertical line 32 which is standard line of rotation driving member 13. Rotation angle θ_1 deviated from vertical line 32 output from angular transmitter 29 is equal to an offset angle θ of light axis of distance measuring member 14 deviated from vertical line 33 ($\theta = \theta_1$). Assuming that R is a distance from rotation center 30 to reference point 34 of distance measuring member 14 and l is a distance obtained by measuring distance calculator 26 as well as the first embodiment, a vertical distance H and horizontal distance L from rotation center 30 to a measuring point on road surface are obtained by the following equations.

$$H = (R+l) \cos \theta_1$$

$$L = (R+l) \sin \theta_1$$

Consequently, in the road convex or concave calculator, already-known R, measuring result l and θ_1 from angular transmitter 29 of rotation driving member 13 are used to calculate H and L. The calculated vertical distance H and horizontal distance L between rotation center 30 and the measuring point on the road surface are fed to display device 17 and plotted in a display of display device 17.

Fig. 12 shows an example of a measured result, minimum scanning rotation θ_{1MIN} is 18.4 degree and maximum scanning rotation angle θ_{1MAX} is 59.0 degree, measuring width is 4 m. The lengths in Fig. 12 are shown in mm, each measuring point is plotted by calculated vertical distance H and calculated horizontal distance L between the measuring point and rotation center 30.

As explained above, it is possible to reduce a size and weight of the apparatus as well as the first embodiment. In addition, as the apparatus is positioned on sidewalk or outside of the road ER, there is no need to control cars on the road around the apparatus. Therefore human labors, costs, time which

are required to control the cars, can be eliminated, and traffic congestions which would be caused by the apparatus can be avoided. Further, the operations on the roads can be avoided.

Fig. 13 is an example that the apparatus shown in Fig. 11 is mounted on handcart or cart 70 which is moved by a driving mechanism of its own. When handcart or cart 70 stops at the measuring positions 1, 2, , ..., as shown, distances from the positions 1, 2, ..., to the road RD in a direction traverse to the road are measured after rotation driving member 13 and the plane portion on the top of the flame 11-1 are adjusted to be horizontal.

Alternatively, in the embodiment shown in Fig. 1, flame 11 can be replaced with flame 11-1 shown in Fig. 11 or Fig. 13 and can be positioned on sidewalk or outside of the road.

In above embodiments, distance measuring member 14 includes light wave distance measuring equipment 19, however it is possible to use conventional measuring member 4, and infrared rays, or ultrasonic waves can be replaced with laser lights.

As explained above, according to this invention, it is possible to reduce a size and weight of the apparatus compared to the road width.

Further, operators do not have to get out of the vehicle during measuring and they do not have to unload the apparatus from the vehicle once the apparatus is mounted on the vehicle. As a result, human labors and dangerous works on roads can be eliminated.

In addition, the case where the apparatus is positioned on sidewalk or outside of the road ER, there is no need to control cars on the road around the apparatus. Therefore human labors, costs, time which would be required to control the cars, can be eliminated, and traffic congestions which would be caused by the apparatus can be avoided.

Further, costs for producing the apparatus can be decreased because its measuring mechanism is simple.

Having described the preferred embodiments of the invention with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments, and that various changes and modifications may be effected therein by one skilled in the art without departing from either the scope or spirit of the invention as defined in the appended claims.

CLAIMS:

1. An apparatus for measuring a shape of a road surface mounted on a vehicle, comprising; rotation driving means for generating rotation motion in a vertical plane and for outputting a signal concerning its rotation angle; inclinometer means for detecting an inclined angle of said rotation driving means, distance measuring means for measuring distance from the distance measuring means to the road surface with rotating by rotation motion of said rotation driving means; data processing means for calculating a vertical distance and horizontal distance between the apparatus and the road surface by means of the inclined angle detected by said inclinometer means and the rotation angle detected by said rotation driving means.

2. The apparatus for measuring a shape of a road surface according to claim 1, wherein said distance measuring means is a light wave distance measuring equipment measuring a distance by emitting a light wave toward the road surface and by receiving a reflected light from the road surface.

3. The apparatus for measuring a shape of a road surface according to claim 1 wherein said rotation driving means includes pulse motor means for generating the rotation motion and pulse motor driver means for driving said pulse motor means, said pulse motor driver means outputting the signal regarding to said rotation angle.

4. The apparatus for measuring a shape of a road face according to claim 1 wherein said rotation driving means includes pulse motor means for generating the rotation motion and transmission means for transducing said rotation motion into a reciprocal linear motion and further for transducing said reciprocal linear motion into a rotation motion about a certain rotation center in a substantial vertical plane and pulse motor driver means for driving said pulse motor, said pulse motor

driver outputting the signal regarding to said rotation angle.

The Patent Office

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Application No:	GB 9525498.3	**Examiner:**	Dr E P Plummer
Claims searched:	all	**Date of search:**	27 February 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4D(DLAB, DLPA, DAB, DRPB, DLPX, DLRC, DLRE, DLRG, DLRJ, DLRP, DLRU, DLRX); G1G(GRE,GPX)

Int Cl (Ed.6): G01B, G01C, G01S

Other: Online:- WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	GB2265274A	STUTTLE & HOGG - whole document	1-3
Y	GB2151872A	HONDA - whole document, but page 3 lines 36 to 39 in particular	1-3
Y	GB1583737	FRANZ PLASSER - whole document	1-3
Y	GB1234427	ATLAS COPCO - whole document	1-3
Y	EP0170038A	ERWIN SICK GMBH - whole document	1-3
Y	US4796998	PASCO CORP - whole document	1-3

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& Member of the same patent family	E Patent document published on or after, but with priority date earlier than, the filing date of this application.